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NASA ADVISORY COUNCIL

Human Exploration and Operations Committee

July 27-28, 2015

NASA Jet Propulsion Laboratory
Pasadena, California

MEETING MINUTES

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Kenneth Bowersox, Chair

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Bette Siegel, Executive Secretary

Human Exploration and Operations Committee
NASA Jet Propulsion Laboratory
Pasadena, CA
July 27-28, 2015

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NASA ADVISORY COUNCIL
Human Exploration and Operations Committee

NASA Jet Propulsion Laboratory
Building 186—von Kármán Auditorium
Pasadena, CA

PUBLIC MEETING MINUTES
July 27-28, 2015

Monday, July 27, 2015

Call to Order and Welcome

Dr. Bette Siegel, Executive Secretary for the NASA Advisory Council (NAC or Council) Human Exploration and Operations (HEO) Committee, called the public session of the HEO Committee to order at 10:00 a.m. She announced that the meeting was a Federal Advisory Committee Act (FACA) meeting and, therefore, would be open to the public. Minutes would be taken and posted on-line, along with the presentations. There would be an opportunity for the public to make comments towards the end of the meeting, and she asked for any questions or comments to be held until that time. Dr. Siegel noted that the HEO Committee would be joining the NAC Technology, Innovation, and Engineering (TI & E) Committee at 1:00 p.m. for a joint meeting.

Mr. Kenneth Bowersox, HEO Committee Chair, welcomed everyone and introduced the first speaker, Mr. Gregory Williams, Deputy Associate Administrator (DAA) for Policy & Plans, Human Exploration and Operations Directorate (HEOMD).

Status of the Human Exploration and Operations Mission Directorate

Mr. Williams congratulated NASA Jet Propulsion Laboratory (JPL) and the Space Communications and Navigation (SCaN) and Deep Space Network (DSN) teams for their work in making the New Horizons spacecraft successful in its voyage to Pluto. Images of Pluto's surface were shown.

Mr. Williams provided an update on the status of the Human Exploration program. He discussed the "squid" chart showing NASA's plans for the journey to Mars. He described the 42 Soyuz launch and International Space Station (Station or ISS) Increment 43.

Mr. Williams discussed the Commercial Crew Program (CCP). He explained that commercial transportation is vital to expanding the commercial market for low-Earth orbit (LEO) services. CCP will re-establish the capability to launch astronauts from U.S. soil. CCP will increase the ISS crew time available for research by an amount equivalent to one additional astronaut dedicated to research. Boeing and SpaceX are advancing their Commercial Crew Transportation Capabilities (CCtCap) contract designs. Hardware is actively being built and tested to inform design. Mr. Williams asserted that NASA maintains adequate insight into what its commercial partners on CCtCap contracts are doing. Adequate funding is needed to achieve safe, reliable, and cost-effective commercial crew transportation services.

Mr. Williams presented and reviewed a chart on Exploration Systems Development (ESD). He noted that the Space Launch System (SLS) has conducted a Critical Design Review (CDR). The Orion CDR will be conducted in the fall. The CDR for Ground Systems Development and Operations (GSDO) will be conducted in the late fall.

He discussed the Asteroid Redirect Mission (ARM). It is a capability demonstration mission and has been approved to proceed into Phase A. NASA has selected Option B, which is going to a large asteroid and bringing a boulder from it back to cislunar space. The next design review for ARM will be in October 2015. The mission still needs Congressional approval. Mr.

Williams asserted that ARM is a vital part of the Proving Ground to demonstrate docking and extravehicular activity (EVA) capabilities.

Mr. Williams discussed the Evolvable Mars Campaign (EMC). A chart summarizing recent Mars study philosophies was reviewed. Mr. Williams explained that NASA is using an architecture that is open in order to accommodate new partnerships and new ideas. In that way, decisions would not have to be made before they are necessary. He reviewed a chart comparing the EMC to Mars Design Reference Architecture (DRA) 5.0.

Mr. Williams described the successful launch of the Soil Moisture Active Passive (SMAP) observatory and the Magnetospheric Multiscale (MMS) mission. A chart was presented showing HEOMD activity in 2015. He reviewed a chart showing HEOMD's 2015-2016 launch schedule. Mr. Williams discussed NASA communication priorities. He noted that NASA is doing a great deal to leverage a "shoestring" budget in order to communicate with the general public, the education community, and NASA's stakeholders.

Mr. Richard Malow asked when the first crewed commercial crew mission would be flown. Mr. Williams responded that the launch is scheduled for early 2018, but could change depending on the 2016 appropriation.

Mr. Bowersox thanked Mr. Williams for his presentation.

Human Journey to Mars Thoughts on an Executable Program

Mr. Bowersox introduced Dr. Firouz Naderi, Mr. Hoppy Price, and Mr. John Baker, all from JPL. They briefed the Committee about their study on a potential executable program for sending humans to Mars. Dr. Naderi explained that the study was aimed at showing an example—an "existence proof"—that a journey to Mars using technologies that NASA currently is pursuing is plausible on a time horizon of interest to stakeholders and without large spikes in NASA's budget. The study describes a technical mission architecture and what it takes to make that architecture executable. Dr. Naderi explained that an executable program requires balancing several sometimes competing constraints on technical feasibility, fiscal affordability, stakeholders' interest horizon, acceptable risk, international and private sector engagement, and political realism across several administrations. Managing all these together is a program architecture that he referred to as "threading the eye of the needle."

Two competing constraints meet head-on: the limit on the human spaceflight (HSF) annual budget and delivering on a time horizon that anyone cares about. He explained that the way to stay affordable and yet deliver engaging missions within the interest horizon of stakeholders is to break up the journey into several staggered mission campaigns and rely on a minimal architecture or limited set of elements. The first campaign would be a mission to the Mars system, with a landing on Phobos. The second campaign would be a short 24-day stay on the surface of Mars. The third campaign would be longer – a one-year stay on Mars. The later campaign would include building infrastructure for a permanent stay on Mars. Dr. Naderi presented a chart showing the building blocks for a minimal architecture. He described the importance of pre-positioning assets. He explained that mission architectures need to be checked for affordability and that mission costs need to be verified by a non-advocate third party. For a journey to Mars to remain in the interest horizon of today's stakeholders, humans need to go in the early 2030s. Experience on the Moon and in cislunar space can be beneficial; however, those activities must be weighed against a delayed timetable for a human presence at Mars. Dr. Naderi advised that the Nation cannot have two space programs simultaneously and that NASA should begin thinking about the ISS end game. A coherent long-term strategy beyond the five-year budget cycle should be articulated; however, it would describe an intention that everybody would know might change.

Mr. Price discussed a possible mission to Mars orbit and Phobos. He described the overall architecture concept for the mission and the plans for getting cargo to high Mars orbit (HMO) and Phobos, getting crew to HMO, getting crew from HMO to Phobos and back to HMO, and the plan for returning to Earth. A graphic showing a Phobos base concept was presented. In response to a question from Mr. Bowersox, Mr. Price explained that a distant retrograde orbit (DRO) as a staging ground was not being considered because it required more propulsion and more mass. He described the attributes for a 24-day Mars surface stay. It would require six SLS launches. The total round-trip would be approximately 900 days. A graphic was used to show the potential descent/ascent vehicle (DAV). Mr. Price discussed supersonic retro-propulsion

(SRP), which would be needed for landing large payloads on Mars. He presented a slide showing an entry, descent, and landing (EDL) concept for a blunted-body Mars lander.

Six types of vehicles would be needed to enable crewed missions to the Mars surface for a short stay: Orion, six SLSs, two solar electric propulsion (SEP) tugs, two deep space habitats, three in-space chemical propulsion stages, and a Mars lander. In response to a question from Mr. Joseph Cuzzupoli, Mr. Price explained that water and other waste materials would be used to form a shelter from radiation events; however, no one has come up with a practical way to mitigate the risk from galactic radiation, which would impose a five percent greater risk of developing cancer. Mr. Price described a possible one-year Mars surface mission. It would require ten SLS launches.

Mr. Baker discussed the timeline and budget for the Mars journey architecture. He presented charts showing a notional timeline and a notional SLS flight manifest for all the steps needed through a one-year surface mission to Mars. He described the need for a cost "sanity check." He noted that The Aerospace Corporation had performed a cost assessment and determined that meeting the study team's self-imposed cost constraint is plausible. Charts were presented showing that the JPL architecture, with ISS ending in either 2024 or 2028, would be affordable with the HSF annual budget adjusted for inflation.

Mr. Williams explained that after the JPL study was published, NASA's teams coordinated with Dr. Naderi, Mr. Baker, and Mr. Price. Both NASA and the JPL study emphasize the need for continuity and sustainability. One area of difference that they will continue to discuss is the use of cislunar space to demonstrate capability and serve as a stage for flights to Mars. Mr. Williams noted that the JPL study has helped to correct the notion that the cost to go to Mars is unfeasible.

Dr. David Longnecker stated that the presentation was exceptionally well-done. He observed that the ARM had not been mentioned, yet is heavily relied upon as a stepping stone in NASA's current plan. Dr. Naderi responded that he mentioned that pre-positioning is based on ARM technology development. Mr. Richard Malow stated that the presenters did a "great job" and "they laid out something that leads somewhere." He commented that NASA's human program "is still at sea." Mr. Williams noted that the JPL study was performed with JPL discretionary funds. He noted that the study's premise—that a firm plan all the way to Mars is necessary—is not shared by NASA. Dr. Naderi added that JPL's discretionary funding came from NASA and that the discretionary funding available for the study had been exhausted.

Mr. Bowersox stated that having a group similar to the JPL study team providing an independent perspective was useful.

Mr. Bowersox thanked Dr. Naderi, Mr. Price, and Mr. Baker for their presentation.

Adjournment

The Committee meeting was adjourned until the afternoon.

NAC Human Exploration and Operations Committee / NAC Technology, Innovation, and Engineering Committee

Call to Order and Welcome

Mr. Mike Green, Executive Secretary for the TI & E Committee called the public session of the joint meeting of the HEO Committee and the TI & E Committee to order at 1:00 p.m. He introduced Dr. William Ballhaus, TI & E Committee Chair, Mr. Bowersox, and Dr. Siegel. Mr. Bowersox said he looked forward to working with Dr. Ballhaus and the TI & E Committee.

Overview of Space Technology

Mr. Green introduced Mr. Stephen Jurczyk, AA, Space Technology Mission Directorate (STMD), who gave an overview of STMD and described how it collaborates with the HEOMD. Mr. Jurczyk explained that STMD is the "cross-cutting" space technology group for the Agency. He noted that previous incarnations of the space technology development program had been accused of "playing in the sandbox" and not developing anything. STMD intends to avoid that by using a systems approach. He reviewed STMD's guiding principles for space technology programs. A graphic was presented on the technology path to pioneering space. He explained how space technology drives exploration. Space technology will focus investments in eight thrust areas that are key to future NASA missions and enhance national space capabilities. Those areas are: high-power SEP, space optical communications, advanced life support and resource utilization, Mars EDL systems, space robotics systems, lightweight space structures, deep space navigation, and space observatory systems.

Mr. Jurczyk reviewed STMD's space technology portfolio, which has three divisions. Transformative and Crosscutting Technology Breakthroughs covers technology demonstration missions, game changing development, and the small spacecraft technology program. Pioneering Concepts and Developing the Innovation Community has NASA Innovative Advanced Concepts (NIAC), Space Technology Research Grants, and the Center Innovation Fund. Creating Markets and Growing the Innovation Economy covers Centennial Challenges, flight opportunities, and Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR).

Mr. Jurczyk reviewed STMD's FY 2016 President's Budget Request. He discussed STMD and HEOMD Advanced Exploration Systems (AES) development objectives. He explained that there are three major categories of cooperation between AES and STMD: (1) deliveries, where STMD matures technology and delivers it to AES for system-level evaluation; (2) partnerships, where STMD and AES co-fund the development of technologies that are of mutual interest; and (3) coordination, where STMD and AES define specific divisions of responsibility within a technical discipline area. Mr. Jurczyk described STMD investments to advance the future capabilities of the SLS and Orion. STMD investments to advance human exploration were described. Examples were provided to show how STMD aligns with the aerospace industry.

Mr. Jurczyk discussed a chart entitled "Advancing Mars Capabilities: Progress through Missions to Go and Land." He described STMD's university partnership program. A graphic was presented showing the names of STMD's space technology partners. He reviewed key milestones in 2015-16. He discussed high power SEP. He described technology investments in optical space communication, the Deep Space Atomic Clock, Advanced Launch Systems, Advanced Life Support and In-situ Resource Utilization (ISRU), and EDL. Mr. Jurczyk described a recent successful Low Density Supersonic Decelerator (LDSD) flight test. He discussed how STMD is working with other government agencies. Current engagements include the Green Propellant Infusion Mission partnership with the Air Force, partnership with the Defense Advanced Research Projects Agency (DARPA) on "Next Generation Humanoid for Disaster Response," collaboration with the Department Of Energy in new battery chemistries, and collaboration with Air Force Space Missile Command to develop a contract mechanism for low cost access to space.

Mr. James Reuther, Deputy AA for STMD, described how STMD brokers arrangements for new technologies to be used on missions. HEOMD and the Science Mission Directorate (SMD) help rank and prioritize STMD investments at the middle and high Technology Readiness Levels (TRLs). When partners agree to co-fund a new technology, STMD moves that item up on STMD's priority list. He noted that it is important to have a sustained technology development program with a pipeline that can be leveraged and is seen as being trustworthy. Dr. Ballhaus explained that the program manager has to set the

acceptable level of risk and that new technologies coming in at specific milestone points could serve to reduce risk, lower cost, accelerate schedule, or improve performance. He suggested introducing new technologies at specified milestone points with criteria that would attract the technologist to compete in order to be able to meet those milestones and meet the criteria to get baselined into the project. Doing so would require some level of technology demonstration and risk reduction to give the project manager confidence that new technology would work and would be available in time to positively affect the project. The new technology would not be in a position to adversely affect the project because it would not be on the baseline. Mr. Reuther stated that this is done on some projects.

Mr. James Odom requested that Mr. Jurczyk identify the top two technologies developed by STMD that are being used in a program. Mr. Jurczyk responded that there were none. He added that the five-meter Composite Cryotank Technologies and Demonstration (CCTD) project needs to be infused in a test. Mr. James Voss asked how it is determined when to dedicate resources to new technologies. Mr. Jurczyk responded that STMD has 15 Technology Roadmaps distilled from the priorities of the mission directorates. Those roadmaps are used to develop the STMD Strategic Investment Plan.

Mr. Green thanked Mr. Jurczyk for his presentation.

Evolvable Mars Strategy – HEO Technology Development Efforts

Mr. Green introduced Mr. Jason Crusan, Director, HEOMD AES. Mr. Crusan briefed the two committees on the EMC and technology development. He began his presentation with a quotation from President Obama:

"Fifty years after the creation of NASA, our goal is no longer just a destination to reach. Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite. And in fulfilling this task, we will not only extend humanity's reach in space -- we will strengthen America's leadership here on Earth."

Mr. Crusan noted that NASA Strategic Plan Objective 1.1 is to "Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration."

Mr. Crusan described seven strategic principles for sustainable exploration:

- implementable in the near-term with the buying power of current budgets and in the longer term with budgets commensurate with economic growth;
- exploration enables science and science enables exploration, leveraging robotic expertise for human exploration of the solar system;
- application of high TRL technologies for near term missions, while focusing sustained investments on technologies and capabilities to address challenges of future missions;
- near-term mission opportunities with a defined cadence of compelling and integrated human and robotic missions providing for an incremental buildup of capabilities for more complex missions over time;
- opportunities for U.S. commercial business to further enhance the experience and business base;
- multi-use, evolvable space infrastructure, minimizing unique major developments, with each mission leaving something behind to support subsequent missions; and
- substantial new international and commercial partnerships, leveraging the current ISS relationships while building new cooperative ventures.

He described the Global Exploration Roadmap. He stated that there is a difference between design reference missions and design philosophy. A chart was presented to compare DRA 5.0 with the EMC. He explained that DRA 5.0 is a 2009 global science-driven approach for the human exploration of Mars, with emphasis placed on mission return with reasonable risk. The EMC, on the other hand, is an ongoing architectural trade analysis to define the capabilities and elements needed for a sustainable human presence on Mars. A graphic was presented showing the EMC as a pioneering approach to exploration involving three zones: Earth Reliant, the Proving Ground, and Earth Independent. The EMC goal is to define a pioneering strategy and operational capabilities that can extend and sustain human presence in the solar system, including a human journey to explore the Mars system starting in the mid-2030s. Mr. Crusan described the internal analysis team members.

He noted that external inputs are received from international partners, industry, academia, and Strategic Knowledge Gap (SKG) analysis groups.

Mr. Crusan discussed EMC plans for FY 2016. He reviewed a chart on recent accomplishments. He described the challenges involved in transporting crew and cargo to and from deep space. The SLS will be used to transport crew and cargo to cislunar space. The Orion will support crew during that trip. Commercial launch vehicles (LVs) will deliver logistics and small cargo to cislunar space. Habitation will be needed to protect and support crew in deep space for up to 60 days in cislunar and up to 1100 days in the Mars vicinity. Mr. Crusan explained that any initial, short-duration habitation module in the Proving Ground of cislunar space would serve as the initial building block required for Mars-class habitation. He described the challenges for in-space transportation. He presented a chart showing SLS Block 1B and mission element concepts under study.

Mr. Crusan discussed the near-term objectives in the Earth Reliant zone, where exploration capabilities will be developed and validated. Routine U.S. commercial crew transportation to LEO will be acquired. Proving Ground objectives were described. These include validating SEP, using lunar DRO as a staging point for large cargo masses on route to Mars, ISRU in micro-gravity, and operations with reduced logistics capability. A graphic was presented showing a "split mission" concept for getting to Mars and returning to Earth. Mr. Crusan reviewed a chart on the NASA Technology Roadmaps and Investment Plan. He described how commercial opportunities in space align with the Exploration program.

Mr. Crusan stated that AES is engaged in the rapid deployment and testing of prototype systems and in the validation of operational concepts to reduce risk and cost of future Exploration missions. He noted that AES had 580 civil servants in FY15. He described AES' work in crew mobility, deep space habitation systems, ground operations, and robotic precursor activities. He described the Bigelow Expendable Activity Module (BEAM), a commercial inflatable module. It will be launched on SpaceX-8 for testing on the ISS. The Morpheus Project was described. It is a prototype planetary lander capable of vertical takeoff and landing. It is designed to serve as a vertical testbed (VTB) for advanced spacecraft technologies. The Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative is establishing multiple no-funds-exchanged Space Act Agreement (SAA) partnerships with U.S. private sector entities. The purpose of those SAAs is to encourage the development of robotic lunar landers that can be integrated with U.S. commercial launch capabilities to deliver payloads to the lunar surface. A chart was presented to show a basic "space internetworking service" in a disruption-tolerant network. Exploration Mission-1 (EM-1) secondary payloads were described. They include CubeSats for investigating the effect of space radiation on simple organisms, remote sensing of lunar volatiles, and a flyby of a near-Earth asteroid.

Mr. Crusan discussed SKGs. He described common themes across potential destinations. He described the "three Rs" for enabling human missions: radiation, regolith (soil on either the Moon, Mars, Martian moons or asteroids) and reliability. He explained that filling the SKGs requires a well-balanced research portfolio. Mr. Crusan described the next rover NASA will send to Mars in 2020. It will carry seven instruments to conduct science and exploration technology investigations to address SKGs for human exploration.

NASA has released the Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement (BAA). Mr. Crusan explained that it is an effort to stimulate deep space capability development across the aerospace industry. The BAA seeks proposals for concept studies and technology development projects in three key areas: advanced propulsion, habitation, and small satellite missions that would fly as EM-1 secondary payloads. Dr. Ballhaus commented that BAA activities require significant industry investment. He asked about the areas in which industry was investing. Mr. Crusan responded that there is a lot of growth in the electric propulsion industry. There also is a huge growth in small satellites.

Mr. Crusan discussed the "pull" that Mars vicinity missions provide for technology development. He presented a chart showing how Earth and the Moon interact in cislunar space. He explained that a spacecraft at Distant Retrograde Orbit (DRO) is actually orbiting the Earth at a distance just past the Moon; however, when viewed from the Moon, the orbit looks like an ellipse around a point in space referred to as a "halo orbit." Dr. Ballhaus observed that every system in national security space is undergoing serious redevelopment.

Mr. Bowersox thanked Mr. Crusan for his presentation.

Hydrocarbon Engine

Dr. Ballhaus introduced Mr. Bill Hill, DAA for Exploration Systems Development, HEOMD ESD, and Mr. Jim Norman, Launch Services Program (LSP) Director. Mr. Hill discussed the HEOMD response to the NAC finding regarding the "Domestic Hydrocarbon Rocket Main Engine." The NAC finding stated:

"The Council believes that it is important for NASA and the nation to assess the need for a new domestic alternative to the currently available foreign hydrocarbon rocket main engines, and to invest accordingly. The Council also believes NASA can and should play a key role in this activity, especially in the development and understanding of advanced materials and metallurgy technologies for a future domestic hydrocarbon rocket main engine."

In response to the NAC finding, HEOMD stated that (1) NASA did support and provide input to the Air Force's RD-180 study, and (2) NASA participated in the review of the responses to the Air Force's Request for Information (RFI) for engine and launch systems. NASA is in the process of completing its own liquid oxygen (LOX)/hydrocarbon studies. NASA has spent approximately $47 million (M) on hydrocarbon engine and other related development work. Part of the FY15 funding will support a joint development test with the Air Force. Although the study activity may continue into FY16, NASA's funding for these activities ends with FY15. NASA has offered the use of its facilities and expertise to both the Air Force and to U.S. industry.

Mr. Norman noted that the Advanced Booster Engineering Demonstration and Risk Reduction (ABEDRR) program has awarded four contracts to reduce risks and enhance affordability for a wide range of future booster concepts. Two efforts are specifically focused on risk reduction for LOX rocket propellant (RP) propulsion. Work on F-1B engine risk reduction was described. Mr. Norman discussed plans for a full-scale, oxygen-rich staged combustion demonstration. The integrated test article is on track for testing in the first or second quarter of FY17. CDR is planned for September 2015.

Dr. Ballhaus thanked Mr. Hill and Mr. Norman for their presentation.

NASA Launch Services Overview

Dr. Ballhaus reintroduced Mr. Norman and then introduced Mr. Darren Bedell, Technical Integration Manager, Launch Services Development, LSP.

Mr. Norman turned the presentation over to Mr. Bedell, who described LSP's goal: get NASA's missions launched on orbit, on time, and on budget. A chart showing the agencies decision chain of command for launches was reviewed. It shows where LSP, CCP and CRS fit within HEO and relationship of LSP to the other programs. Mr. Bedell explained that LSP provides insight, approval, and advisory services for program management, analysis, engineering, integration, and launch operations. LSP has 259 civil servants and 180 contractors, averaging over 15 years in launch experience. It has an over 97 percent on-orbit mission success rate.

Dr. Ballhaus commented that new vehicles developed by commercial entities historically have a failure rate that is initially high. On the other hand, new vehicles developed under government mission assurance have a high success rate. He asserted that the reason is lessons learned get transferred. The government has access to the lessons learned and applies it to new programs. He expressed concern about learning from a succession of failures when launching commercial crew.

Mr. Bedell presented a chart showing LSP's current and future fleet. He noted that LSP performed certification is governed by NASA Policy Directive (NPD) 8610.7, *Launch Services Risk Mitigation Policy for NASA-Owned or NASA-Sponsored Payloads,* which he described. Mr. Norman commented that the Atlas V and Antares rockets both use Russian engines and that NASA is not prohibited from acquiring launch services that use Russian engines.

Mr. Michael Lopez-Alegria asked whether LSP is allowed to consider non-U.S. providers. Mr. Bedell responded that the Agency at the mission level can acquire foreign LVs on a non-exchange-of-funds basis. The James Webb Space Telescope (JWST) is an example. LSP, however, does not directly purchase foreign LVs.

Mr. Lon Levin asked whether LSP takes into consideration a provider's ability to stay in business, in addition to its technical and engineering qualifications, when LSP evaluates the company's LVs. Mr. Bedell responded that financial responsibility is a criterion LSP considers before awarding the company a contract.

Mr. Bedell stated that suppliers could launch from whatever launch sites meet mission requirements and that close the company's business case. He noted that the cost to NASA for travel has to be considered because it is significant over a three-year campaign for some remote locations. In response to a question from Dr. Ballhaus, Mr. Bedell explained that the LSP Program Manager is the certifying official and has been delegated responsibility for issuing the initial certification under NPD 8610.7 and the Certificate of Flight Readiness (CoFR). If the mission is not ready to go, there is no need to withdraw the certification; the mission does not go. Dr. Ballhaus commented that the same process is followed by the Air Force.

Mr. Bowersox asked about the process followed for CRS when LSP is acting in an advisory role and observes a problem. Mr. Bedell responded that LSP does not have a role in CRS on launch day, which is in accordance with a choice that had been made by the Agency. The LSP's advice, however, does go through NASA's launch readiness process, which informs the ISS determination on whether the ISS is ready to accept the cargo. In response to a question from Dr. Ballhaus, Mr. Bedell clarified that neither NASA nor LSP is polled at a Flight Readiness Review (FRR) for the CRS vehicle's launch. In response to a question from Mr. Bowersox, Mr. Bedell explained that the process on launch day for CCP "is a work in progress." LSP's role in the CCP is to look at the build for each of the vehicles. Dr. Ballhaus asked what accountability LSP has for JWST's mission success, which would be launched on a foreign LV. Mr. Bedell explained that the overall accountability for NASA does not change. Dr. Ballhaus advised that accountability should be viewed from the perspective of the day after a failure.

Mr. Bedell described the LSP acquisition strategy. LSP is currently awarding new contracts for LVs under the NASA Launch Services (NLS) II Contract. LSP customer's missions are subject to NPR 8705.4, *Risk Classification for NASA Payloads which defines their risk posture.* In response to a question from Ms. Shannon Bartell, Mr. Bedell explained that mission assurance is treated the same for all recurring payloads under the NLS contract because even a class "C" payload becomes a class "A" payload on launch day. Depending on the mission risk tolerance informed by NPR 8705.4, LSP uses a low-risk-tolerant approach (NLS), a tailored approach, or a high-risk-tolerant approach to acquisition. Dr. Ballhaus advised that it is important to select suppliers that would have a high enough flight rate to maintain both mission success and reasonable prices.

Mr. Bedell described the components of the LSP budget. Ninety-five percent of its costs are incurred through fixed-price contracting, where the contractor assumes all risks and the price remains constant regardless of the cost of production.

Mr. Bedell discussed a chart illustrating NASA space launch technical oversight. He explained that regardless of how oversight is divided between the commercial provider and the government, NASA's accountability for mission success is 100 percent for all missions. For JWST, NASA made a decision to use a reliable foreign launch service, the Ariane V. Mr. Dick Mallow commented that the European Space Agency (ESA) had offered the Ariane as one of its contributions to the mission and for that reason was receiving 15 to 18 percent of the mission's time. Mr. Bedell explained that LSP exercises no responsibility over the Ariane, but for example would become involved in assessing compliance with NPD 8610.7 if ESA were to change its configuration. In response to a question from Dr. Ballhaus, Mr. Bedell clarified that NASA at all times remains 100 percent accountable for the mission's success. In response to a question from Mr. Bowersox, Mr. Bedell explained that NASA has a seat in the decision making process for JWST's launch on the Ariane and that NASA attends the launch readiness meetings. He discussed LSP's flow-down requirements for the driving NASA Policy Directives. Charts on LSP mission assurance, certification requirements, and launch readiness were reviewed. In response to a question from Dr. Ballhaus, Mr. Bedell stated that LSP has not had any failures due to accountability issues related to insight or oversight. Dr. Ballhaus commented that the root cause for the Titan failures was an absence of individual accountability, which he advised is a key element for mission success.

Mr. Bedell discussed LSP's advisory role on CRS. The guiding principle was that the commercial provider, not NASA, would be responsible for the CRS launch success. LSP's engineering support mainly focused on LV design and qualification. He

explained that Safety and Mission Assurance (SMA) focused on build processes and insight into specific vehicles, as requested. The NASA Technical Authorities for CRS missions are at the NASA Johnson Space Center (JSC). He described the support that LSP provides to the CCP. LSP provides support on CCP programmatic and technical tasks related to launch services. It has advised on firm-fixed-price contracting and certification process lessons learned. It has participated in the CCtCap Source Evaluation Board (SEB). It is supporting CCP LV tasks for Commercial Crew Integrated Capability (CCiCap) SAA milestone reviews and Certification Products Contract (CPC) deliverables. Mr. Bedell explained that LSP and the CCP have defined LSP support for the certification phase of the CCP. He noted that certification for CCP is based on compliance to NASA human rating and key ISS Design Reference Mission (DRM) requirements, not to NPD 8610.7. In response to a question from Ms. Bartell, Mr. Bedell explained that LSP is providing the CCP with engineering expertise and is passing knowledge along to them.

Dr. Ballhaus stated that he had tremendous respect for the LSP organization and he thanked Mr. Bedell for his presentation.

Public Comments

Ms. Eva Blaisdell introduced herself as the CEO and founder of the California Space Center. She stated that she represents an emerging interest in commercial space, with the goal of forming a new alliance to support projects. In addition to founding the California Space Center, she represents interests in Poland, France, and elsewhere. She and her partners have a commitment to acquire land next to the Vandenberg Air Force Base. The California Space Center will make a major contribution to American society in understanding the importance of space. She works closely with major investors in Silicon Valley, and she can help identify both business and individual investors. There are abundant funds, but they are dispersed. She indicated that she wanted to make herself available to discuss and solicit ideas. She identified herself as an immigrant who sees that NASA's strength speaks to the strength of this country. She noted that she was particularly interested in LSP, which reflects the interests of her group.

Joint Discussion, Joint Recommendations, and How We Work Together

Mr. Jim Oschmann, a member of the TI &E Committee, suggested providing a recommendation on how STMD and HEOMD could work better together. He acknowledged that they have huge problems from budgetary pressure. Mr. Bowersox suggested a finding that they are working well together. Dr. Ballhaus observed that NASA does not have a mission for the future; it has a range of possible missions. He stated that if NASA had a focused mission, the technology program would be more focused. Ms. Nancy Ann Budden suggested blending technologies on the critical path with budget realities in order to come up with a short list of technologies that could be focused upon. Mr. Bowersox explained that that is the process being used for the EMC. Dr. Ballhaus observed that the key technology risk reduction demonstrations have all been pushed downstream. Ms. Mary Ellen Weber noted that the Senate is proposing a reduction to the STMD budget that is tantamount to a 70 percent cut after taking into account the statutory mandates for the SBIR and STTR Programs. She asserted that the proposal will cripple and decimate what STMD can do for the HEOMD and would render moot any recommendations about collaborating. Dr. Reuther explained that under the Senate reduction, STMD would no longer be able to serve the purpose for which it was created. He stated that the funding dedicated to NASA's research and development (R&D) is not a sustainable level for taking humans to Mars. He added that NASA cannot lead the world if it does not have a technology portfolio that represents a larger portion of its budget. Dr. Pat Condon asserted that there is no sense of urgency because there is no clearly stated end objective.

Mr. Bowersox suggested preparing a finding that STMD and HEOMD work well together, that a roadmap exists for critical technology, and that a delay in executing the roadmap would delay Exploration. Mr. Oschmann, Dr. Ballhaus, and Ms. Budden agreed to draft the finding.

Dr. Ballhaus discussed the financial difficulty that the Atlas program might have if the Atlas V is precluded from being used for national security launches. He noted that the Atlas V is one of the LVs for the CCP. Mr. Bowersox suggested having the CCP brief both committees on that issue at a future joint meeting.

Adjournment

The joint meeting of the HEO Committee and TI & E Committee was adjourned at 5:50 p.m.

NAC Human Exploration and Operations Committee

Tuesday, July 28, 2015

Call to Order, Welcome and Opening Remarks

Dr. Siegel called the HEO Committee meeting to order at 8:00 a.m. and welcomed everyone back. She announced that it would be a public meeting, and that minutes would be taken and posted with all presentations. She introduced Mr. Bowersox.

Communication Strategy

Mr. Bowersox introduced Dr. Alotta Taylor, Director, Strategic Integration and Management Division, HEOMD, who briefed the Committee on HEOMD's communications strategy. Dr. Taylor explained that NASA's responsibility to communicate arises from the 2010 National Aeronautics and Space Act, which mandates that the Administration "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." A chart was presented showing that NASA's communication priorities are Earth, the ISS, Mars, technology, aeronautics, and the solar system and beyond. Dr. Taylor explained that NASA is changing its operational model into one that is strategic, integrated, aligned, and outcome-driven. She described HEOMD's three communication goals. The first is to enhance public and Congressional recognition of the value of human space exploration and the understanding of the capabilities-driven approach to sending humans to Mars. The second goal is to enhance public awareness of the marvels associated with the ISS and its role in advancing human space exploration. The third goal is to enhance public involvement and excitement about human exploration missions through authentic experiences and opportunities to participate. Mr. Bowersox noted that NASA Headquarters and each NASA Mission Directorate has its own communication plan.

Dr. Taylor presented a chart showing how the HEOMD communication strategy aligns with the NASA communications ecosystem, which includes social media, owned media, partnerships, appearances, and earned media. She explained that NASA is excelling in social media. NASA leads the White House in followers on both Facebook and Twitter, and comes in second to National Geographic on Instagram. She noted that NASA employees are allowed to participate freely in social media. Charts were presented on media metrics, showing the total number of times NASA had been mentioned during a recent three-month period. Dr. Taylor described *Time* magazine's coverage of Astronaut Scott Kelly's "Year in Space." She described media coverage over the four Astronauts recently selected to train for Commercial Crew spaceflights.

Dr. Taylor discussed public engagement and outreach. She provided statistics on the Orion test flight. There were 27,000 VIP guests, 157 newspaper front pages, five million visits to NASA.gov, and six hours of live NASA TV coverage. The NASA Facebook page reached 13.5 million people on launch day. The integrated ESD Instagram account, @exploreNASA, reached over 90,000 new followers in less than six months. Dr. Taylor noted that the NASA Headquarters ISS video wall won the 2015 APEX Top Gold Award for exceptional digital signage of interactive technology. She reviewed several charts showing NASA participation at conferences and large-scale events. A graphic was presented on the Exploration Flight Test-1 (EFT- 1) partnership with Sesame Street. She described the interactive exhibit "Destination Station." Dr. Taylor discussed goals for strengthening relationship with museums and NASA visitor centers. The Journey to Mars museum kit was described. Mr. Odom suggested that NASA engage with the Space Camp in Huntsville, Alabama, and its graduates.

Dr. Taylor presented a chart on the "Education Express." She explained that content from the Express message has the potential to be shared through social media with almost 11 million people. Education and collaboration opportunities were discussed. She described a NASA challenge for students to design 3-D containers that could be used in space. It is the second in a series of "Future Engineers" challenges. The #WhySpaceMatters photography competition was described. The competition invites the public to submit photos depicting why space matters to everyone in their daily lives. To participate, participants post a picture and description on Instagram. Astronaut Kelly will announce the winning photo each month by posting it on his @StationCDRKelly Instagram account. A chart was presented on HSF planetarium shows.

Dr. Taylor described the ESD newsletter and space flight awareness program activities. She summarized the HEOMD Communications Strategy: communicate as widely as possible, build communities of fans and followers, and transform them into advocates, ambassadors, creators, and collaborators.

Ms. Bartell thanked Dr. Taylor for providing the presentation charts to Committee members prior to the meeting. Ms. Bartell noted that she is seeing a more comprehensive approach by the Division in attacking different areas. Ms. Budden asked Dr. Taylor for her view on funding for communication and education. Dr. Taylor responded that more is always wanted and that the Division leverages what it receives to the best of its ability.

Mr. Bowersox thanked Dr. Taylor for her presentation.

Exploration Systems Development Status

Mr. Bowersox introduced Mr. Bill Hill, DAA for Exploration Systems Development, HEOMD, ESD, who briefed the Committee on ESD's status. He reviewed a slide showing the "stack" that will be used for missions beyond LEO. The various components and their manufacturers were described. Mr. Hill discussed the ESD EM-1 Integrated Mission Milestone Summary chart. It is a progress monitoring tool for the 2018 July-September launch window. They are working through the CDRs. When the CDRs are completed, they will look at a single launch readiness date. Mr. Bowersox noted that the launch date has moved from late 2017. In response to a question from Mr. Bowersox, Mr. Hill explained that the three critical paths on the schedule for EM-1 are the ESA service module (ESM), Orion, and the core stage. The core stage has run into a delay at the vertical assembly structure at NASA's Michoud Assembly Facility (MAF), where there was an issue with the alignment of the towers that hold the rings. He noted that the vertical assembly structure is used to weld the five barrel sections for the core stage. Mr. Bill Gerstenmaier, AA, HEOMD, advised that NASA is building a system for the future and that it is okay if the different components progress at different rates. In response to a question from Mr. Lopez-Alegria, Mr. Hill explained that a budget increase would not help advance the schedule for EM-1. Any additional funding would be used for EM-2 and eliminate the need to human rate the Interim Cryogenic Propulsion Stage (ICPS). Mr. Gerstenmaier stated that it would be an advantage to get the Exploration Upper Stage (EUS) as quickly as possible. Mr. Odom observed that NASA had control over everything except the ESM and asked how that was being handled. Mr. Hill responded that there are monthly teleconferences with ESA and that there are many challenges being worked out at the lowest and highest levels of the Agency.

Mr. Hill discussed the status of the various components for EM-1. The Orion Integrated Test Lab (ITL) is officially open and will be used for integrated testing of ground systems, SLS, and Orion. In response to a question from Mr. Odom, Mr. Hill responded that independent software validation and verification (V&V) would be conducted at NASA's facility in West Virginia and he noted that the three programs are using an "agile development" approach. Mr. Hill presented a slide on the launch abort system (LAS). Its Attitude Control Motor hot fire test is scheduled for April 2016. The Crew Module is scheduled to be "on-dock" at NASA Kennedy Space Center (KSC) in January 2016. He explained that the ESM is being manufactured for ESA by Airbus and that the avionics have been taken out of the ESM to reduce its complexity. The Crew Module Adapter (CMA)/LAS modal testing begins September 2015. The first EM-1 fairing separation test was conducted in June 2015. The fairings are on track for an on-time delivery in early 2017. The Orion Stage Adapter (OSA) EM-1 test article is complete. The ICPS test article will be delivered to NASA Marshall Space Flight Center (MSFC) in October 2015. A chart on the core stage status was reviewed.

Mr. Hill described the successful RS-25 engine testing on the refurbished test stand at NASA Stennis Space Center (SSC). He explained that NASA had 16 RS-68 engines that would be used for 4 test flights. In response to a question from Mr. Odom, Mr. Hill discussed 3-D printing. It is being used for very small parts and is expected to drastically change manufacturing parts that have complex geometries. Aluminum and copper are now being used. Mr. Gerstenmaier stated that 3-D printing can reduce costs by a third. Mr. Hill reviewed the status of the grounds systems, which include the Launch Equipment Test Facility (LETF), the mobile launcher, modifications at Launch Pad 39B, the crawler-transporter, the Vehicle Assembly Building High Bay 3 platform, and the Multi-Payload Processing Facility. He noted that eleven different construction contracts are involved and that with every contract award there have been challenges and protests that are slowing progress.

Mr. Hill reviewed charts on Orion's major accomplishments and its major schedule milestones. He described the Orion EM-1 manufacturing progress. He noted that every large machine shop in the country has been engaged in the process and that competitors have helped each other to resolve manufacturing issues. He reviewed charts on SLS's major accomplishments and its major schedule milestones. He discussed the RS-25 engine test plan objectives. GSDO accomplishments were reviewed.

In response to a question from Mr. Malow, Mr. Hill explained that the two biggest threats to a launch in three years would be getting the core stage ready and the ESM, which had been delayed by a late start. Mr. Gerstenmaier commented that the ESM is very sophisticated and is the "brains of Orion." It is the highest risk due to the amount of criticality and testing. He added that the problems would have been the same if it had been built by NASA and that NASA is teaching ESA how to do program management again. Mr. Gerstenmaier noted that the level of hardware being produced by the Agency for EM-1 is "unprecedented." In response to a question from Mr. Odom, Mr. Hill stated that the reserve posture for EM-1 "would scare most people." Mr. Gerstenmaier stated that there is not much reserve to throw money at problems and that people have been innovative at coming up with solutions.

Mr. Bowersox thanked Mr. Hill for his presentation.

Asteroid Redirect Mission Status

Mr. Bowersox introduced Dr. Michele Gates, ARM Program Director. Dr. Gates updated the Committee on the status of the ARM. She described the ARM's five objectives. She explained that ARM HSF demonstration objectives in the Proving Ground are an important early step to longer term crew activities in deep space. A graphic was presented showing how the ARM would be a capability demonstration mission for high-efficiency large solar arrays, exploration EVA capabilities, SEP, and deep-space rendezvous sensors and docking capabilities.

Dr. Gates provided an overview of the Asteroid Robotic Retrieval Mission (ARRM). The ARRM formulation guidance was reviewed. Dr. Gates explained that NASA has selected the robotic capture and collection option, formally referred to as "Option B." The target launch date for the robotic mission is December 2020. The formulation guidance for the ARRM includes a $1.25 billion (B) cost-capped cost estimate, excluding the launch vehicle and mission operations. The robotic mission is to be followed by a crewed mission with a December 2025 target launch date. NASA has approval to proceed to begin Phase A for the ARRM. The ARRM is to be interface compatible with EELV-class LVs, the Falcon Heavy, and SLS until final LV selection. ARRM is to provide resources, including power and communications, for future potential visiting vehicles and provisions for future refueling. Dr. Gates presented a slide showing current candidate parent asteroids for the ARRM. NASA will continue to look for additional asteroid targets in accessible orbits.

Dr. Gates discussed a recent ARM BAA. It resulted in $4.9M in awards for 18 six-month studies. In May 2015, NASA issued an RFI for additional spacecraft bus concepts to support the ARRM and in-space robotic servicing. Responses to that RFI would be considered at the Acquisition Strategy Meeting.

NASA is organizing an ARM Investigation Team (IT), which would be preceded by the Formulation Assessment and Support Team (FAST). Those teams will comprise scientists, technologists, and other qualified and interested individuals who would participate in requirement formulation efforts during the initial development phase of the ARRM. They would help identify potential investigations and payloads related to the following key areas: science benefit, planetary defense, in-situ resources utilization benefit and capability and technology demonstrations. The final report of the ARM FAST is to be submitted to NASA in November 2015. The report will be released publicly and available for comment. After the report is finalized, FAST work would be concluded. The IT is a multidisciplinary group that would support ARM program-level and project-level functions including mission formulation, mission design and vehicle development, and mission implementation. The IT would also provide input into extensibility, commercialization, potential secondary payloads, and partnership activities in close coordination with other Agency efforts. The planned structure and milestones for the IT were described.

Dr. Gates discussed ARM external opportunities. She explained that opportunities for commercial and international partnerships exist for both the ARM and the Asteroid Redirect Crewed Mission (ARCM). Dr. Gates concluded her presentation with a chart showing ARM near-term milestones.

In response to a question from Mr. Odom, Dr. Gates explained that the robotic spacecraft would rendezvous with the asteroid and that a designated team would then select a boulder on the asteroid for the spacecraft to acquire.

Mr. Bowersox thanked Dr. Gates for her presentation.

Commercial Crew Program Status

Mr. Bowersox introduced Mr. Phil McAlister, Director, Commercial Spaceflight Development, who briefed the Committee on the status of the CCP. He explained that CCP will re-establish the capability to launch astronauts from U.S. soil. It will increase the ISS crew time available for research by an amount equivalent to one additional astronaut dedicated to research. A chart summarizing SAA milestones was presented.

Mr. McAlister described the status of NASA's partners under the CCtCap contracts. A chart showing Boeing's schedule was presented. Mr. McAlister explained that Boeing's Crew Space Transportation-100 (CST-100) spacecraft can accommodate up to seven passengers or a mix of crew and cargo to LEO destinations such as the ISS or the planned Bigelow station. The design mission is for four crew and 220 lbs of pressurized cargo. The Boeing system comprises the CST-100 spacecraft, the Atlas V, and ground infrastructure. Mr. Bowersox commented that the costs for NASA could increase because the Atlas V relies on the Russian RD-180 engine, and the Air Force has been precluded from using that engine in the future for national security missions. Mr. McAlister responded that the Boeing contract is for a fixed price and covers two test flights and up to six operational missions to the ISS. Cost increases would have to be absorbed by the contractor. Mr. Gerstenmaier explained that six flights are required from both Boeing and SpaceX and are sufficient, at two flights per year, to cover transportation to the ISS through 2023. He added that Boeing may offer, as an alternative to the Atlas V, the Vulcan LV under development by United Launch Alliance (ULA). Mr. McAllister noted that the CST-100 features a weld-free capsule. A chart summarizing Boeing accomplishments to date was discussed. Mr. McAlister stated that multiple Technical Interchange Meetings (TIMs) and other meetings had been held with NASA to provide insight. In response to a question from Mr. Cuzzupoli, Mr. McAlister explained that under the SAAs for Commercial Cargo, NASA had smaller insight teams that were more "hands-off." The CCtCap contracts have an insight clause that gives NASA access to any data needed for the certification process. Mr. Gerstenmaier explained that NASA could perform a study anytime it disagrees with how a contractor is doing something. He stated that "overall, it is a healthy process." Mr. McAlister noted that there are 280 "shall" clauses in the contracts' primary requirements document, and the contractors must demonstrate that the requirements have been closed. In response to a question from Mr. Bowersox, Mr. Gerstenmaier explained that a major structural change made at NASA's request would be cause for the contact to be renegotiated.

The SpaceX CCtCap was reviewed by Mr. McAlister. He presented a chart describing SpaceX's accomplishments. A recent pad abort test was described. There were over 200 sensors onboard the test capsule, numerous cameras, and a simulated crewmember. Mr. McAlister presented a chart showing the SpaceX milestone summary schedule. He described the SpaceX architecture for the Dragon spacecraft segment, the Falcon 9 LV, which uses Merlin engines in an "octaweb" mount, and the ground and operation segment. Dr. Pat Condon asked whether the recent SpaceX accident had caused NASA to rethink its approach to commercial crew. Mr. McAlister responded that it did not. Mr. Bowersox commented that the FAA had licensed the launch and, therefore, had responsibility for the mishap investigation. Mr. Gerstenmaier explained that NASA was willing to take more risk in CRS than in CCP. He added that LSP personnel, which are used to certify high-value spacecraft, would be leveraged for the CCP. Mr. Bowersox requested a briefing on the different levels of certification and on how NASA reaches a "go, no-go" decision. Mr. Gerstenmaier commented that CCP had recently briefed the Aerospace Safety Advisory Panel (ASAP) on that subject. Mr. McAlister noted that over 30 insight forums had been established to increase insight. In response to a question from Mr. Bowersox, Mr. McAlister stated that, on average, NASA would have approximately three to five people on-site for insight at any one time, sometimes more sometimes less. Mr. Gerstenmaier commented that NASA is sensitive, as a government agency, about inundating the contractor with government personnel. In response to a question from Mr. Cuzzupoli, Mr. Gerstenmaier explained that there is a verification plan that gives NASA

the option to conduct inspections, which he believes gives NASA the adequate insight for proper assurance. Mr. McAlister added that there is a verification strategy for every requirement.

Mr. McAlister discussed the CCP budget. NASA's FY 2016 President's Budget Request for CCP is $1.243 B. Fixed-price, Federal Acquisition Register (FAR) contracts with Boeing and SpaceX are in place, and both companies have demonstrated good progress and performance. He noted that ending U.S. reliance on Russia for crew transportation is a priority. Some CCtCap milestones may move from FY 2016 to FY 2017. He explained how Federal law requires that milestones must be funded or "obligated" prior to the contractor beginning work on the milestone. Mr. Gerstenmaier commented that it would violate the Federal Anti-Deficiency Act if NASA were to direct a contractor to work without funds being obligated to pay for the work. Mr. McAlister discussed what would happen if the Agency were to be funded with a Continuing Resolution (CR). If NASA does not receive sufficient funds, the contractors would have to stop work and the contracts would need to be renegotiated, most likely resulting in schedule delays and increased contract costs. Mr. McAlister explained that NASA has no plans to down-select the number of partners in response to a lower-than-requested funding level. He asserted that redundant, crew transportation capability is critically important for robust, safe ISS operations.

Mr. Levin commented that Mr. McAlister had provided "a fantastic presentation." Mr. Bowersox thanked Mr. McAlister for his presentation.

International Space Station Status

Mr. Bowersox introduced Mr. Sam Scimemi, Director, HEOMD ISS. Mr. Scimemi discussed the need to transition HSF from ISS to the Proving Ground and the commercialization of LEO. Mr. Gerstenmaier explained that those are Agency efforts being led by Mr. Scimemi within the overall journey to Mars. Mr. Gerstenmaier noted that two things to be focused on moving forward are modularity and standards. Mr. Scimemi explained that there is need to ensure that (1) HSF transitions without a gap between ISS and cislunar space, and (2) research and technology development in LEO continues seamlessly between ISS end-of-life and commercially available capabilities. He reviewed charts to show the difference between being Earth dependent and Earth independent. Mr. Scimemi noted that the ISS is only 400 kilometers (km) from Earth, while Mars is 228 M km from Earth.

Mr. Scimemi explained that the primary goal for HSF in the Proving Ground is to prepare all the crew-related capabilities needed for long-duration, transit missions to Mars. The Proving Ground would culminate in one-year crewed expeditions in cislunar space, which he referred to as a "shakedown cruise." The goal of a shakedown cruise or multiple cruises would take place towards the end of the 2020s and provide an anchor for other HSF activities and broader scientific objectives. There would be many opportunities for public-private and international partnerships in achieving the one-year duration crewed missions in cislunar space. He stated that there is a need to determine the impact that the transition of HSF from LEO to the Proving Ground may have on the ISS. All the critical research and system demonstrations needed to validate long-duration HSF must be completed on ISS before being applied in the Proving Ground. NASA is now engaged in determining the transitional objectives it wants to accomplish on ISS that could be transferred to cislunar space.

Mr. Scimemi discussed expanding the U.S. economy into LEO. The vision is to have sustained economic activity in LEO enabled by HSF, driven by private and public investments creating value and benefiting Earth through commercial supply and public and private demand. NASA is working with the Center for the Advancement of Science in Space (CASIS), industry, and other government agencies (OGAs) to augment existing relationships and activities with focused initiatives in potential high-payoff, market-enabling areas. NASA is working toward partnering with OGAs to establish long-term policy and regulation to cover ISS and commercially available capabilities. Mr. Scimemi noted that commercial entities are reluctant to take risks in the absence of government regulation. He stated that he intends to present to the Committee at its next meeting a top-level draft of the HSF ISS-to-Proving Ground transition plan and progress towards building the commercial and OGA demand for LEO. He also suggested having CASIS make a presentation to the Committee.

Mr. Scimemi updated the Committee on the status of the ISS. He presented a chart showing the ISS schedule for crew rotation, port utilization, and launches through May 2016. He described the 42 Soyuz crew and the 43 Soyuz crew. He reviewed the major objectives for Increment 44. A chart showing the status of total ISS consumables was discussed. Mr. Scimemi reviewed new ISS vehicle issues. He noted that the Total Organic Carbon (TOC) readings of the ISS Water

Processing Assembly (WPA) had been climbing. There are no spare parts on board for the WPA and, therefore, to keep TOC levels steady, only distillate from the Urine Processor Assembly (UPA) is being processed. Condensate will not be processed as it likely contains dimethylsilanediol (DMSD).

The Committee was briefed by Mr. Scimemi on the status of the vehicles that visit the ISS. He discussed the Progress 59P anomaly. It launched on April 28, 2015, but failed to reach proper orbit. A Russian commission was formed to investigate the failure. NASA formed an independent team to review the anomaly. The most probable cause findings were discussed. The likely cause was a change in the LV configuration. No crew missions are planned on the new configuration through 2020. Mr. Scimemi discussed the SpaceX-7 mission anomaly. SpaceX is leading the investigation, with FAA oversight. NASA is supporting the investigation with LSP, CCP, and ISS personnel. A chart was presented showing a summary of the cargo lost on the SpaceX-7. Mr. Scimemi reviewed the status of the Orbital-4 mission. Orbital has contracted with ULA for an Atlas V launch of the Cygnus spacecraft. It will be the first use of the Atlas with the Cygnus. He noted that the Orbital-3 Mishap Investigation Report had been provided to the FAA by Orbital ATK. Orbital ATK Inc. was formed in 2015 from the merger of Orbital Sciences Corporation and parts of Alliant Techsystems. Mr. Gerstenmaier stated that it had been "tough losing three vehicles," that a lot of research was lost, and that it would be necessary to "run a little leaner on food and water." In response to a question from Mr. Bowersox on the availability of spares critical for redundancy, Mr. Gerstenmaier stated "we are down to zero spares." He added that NASA is "learning how to become Earth independent by necessity." Mr. Gerstenmaier noted that NASA had a contingency EVA capability on the ISS, but not a nominal EVA capability.

Mr. Scimemi discussed the utilization of the ISS. He presented charts showing how crew time has been utilized on Increments 43 and 44. Mr. Bowersox explained that crew members often provide voluntary research time for recreation. Mr. Scimemi discussed ISS research statistics. He presented a chart showing the research lost on SpaceX-7. He described the ISS Research and Development Conference as an "amazing success." He reviewed the progress that CASIS has had in developing the ISS National Laboratory. One driver has been rodent research. Mr. Gerstenmaier noted that the State of Massachusetts was funding research on the ISS. In response to a question from Mr. Lopez-Alegria, Mr. Gerstenmaier explained that private companies were primarily interested in using the ISS for research on pharmaceuticals. He added that the Russian government has announced it will extend the ISS to 2024.

Mr. Bowersox thanked Mr. Scimemi for his presentation.

Public Comments

An opportunity was given for the public to make comments. There were no comments.

NAC HEO Research Subcommittee

Mr. Bowersox introduced Dr. David Longnecker, who briefed the Committee on highlights from the June 20, 2015 meeting of the HEO Research Subcommittee (RS). Dr. Longnecker described the RS's membership. He discussed a draft research plan that the Space Life and Physical Sciences Research and Applications Division (SLPSRAD) had given to the RS for its review and comment. The RS had been impressed by the stature of the scientific community drawn to ISS research and with the quality of the research. The RS noted that the crew time to implement labor-intensive, fundamental research is greatly curtailed in NASA's plans. SLPSRAD had estimated that only approximately two percent of projected crew research time had been devoted to space biology or physical science investigations without collaboration or alignment with CASIS and HRP. Dr. Longnecker presented a chart delineating ISS crew time for NASA research in Increments 45 and 46, showing zero for the prime-adjusted crew time for non-HRP NASA research. The RS concluded that crew time allocations are severely limiting the ability of space biology and physical science to implement NRC guidance or support NASA's strategic objectives. Mr. Gerstenmaier commented that larger portions of rodents could be returned, thereby reducing the time it would require astronauts to perform dissections. He added that NASA is working to reduce the time the ISS crew spends on maintenance. Dr. Longnecker presented a chart identifying important physics questions that could be resolved by the precision measurements available on the ISS. The questions include: What is the dark matter? What is the nature of the dark energy? Did Einstein have the last word on gravity? Are protons unstable? Are there additional space time dimensions?

Dr. Longnecker describe the Cold Atom Laboratory-1 flight investigations. Dr. Siegel explained that many of the proposals for those investigations come from Noble Prize-winning scientists.

Mr. Bowersox thanked Dr. Longnecker for his presentation.

Discussion and Recommendations and Findings

Mr. Bowersox reviewed previous discussions and recommendations by the Committee. The Committee reviewed its work plans for the coming year.

The Committee discussed submitting to the NAC a proposed finding for HEOMD to continue to include parties outside of the EMC team in the effort to develop plans for future exploration. The Committee approved a finding stating:

NASA Human Exploration and Operations Committee Finding

Name of Committee: Human Exploration and Operations Committee
Chair of Committee: Mr. Ken Bowersox
Date of Public Deliberation: July 28, 2015 (HEO Advisory Committee)

Short Title of Finding: Outside Participation in Exploration Mission Planning
The HEOMD is leading an effort to build the technical rationale for a sustainable human exploration effort which will allow humans to pioneer space called the Evolvable Mars Campaign. Inclusion of groups outside the core NASA team in the Evolvable Mars Campaign study process helps to build support for the study results, and also allows for a wider set of creative approaches from which to build the final plans for human exploration. The HEO Committee endorses the HEOMD's current effort to include outside participation in NASA's planning efforts for the Journey to Mars.

The Committee discussed submitting to the NAC a proposed finding to endorse HEOMD's effort to communicate NASA's plans for pioneering space. The Committee approved the following proposed finding:

Name of Committee: Human Exploration and Operations Committee
Chair of Committee: Mr. Ken Bowersox
Date of Public Deliberation: July 27, 2015 (HEO Advisory Committee)

Communication Strategy for Exploration Plans
Finding: The Committee noted a positive improvement in NASA's effort to communicate plans for Pioneering Space, including the Journey to Mars. Because of the critical importance of public engagement in the human exploration program, the committee plans to request future briefings on this topic to monitor progress. During briefings on this topic, the committee members thought that the following aspects of the communication approach were especially important:

1. The existence of a formal strategy to guide communication efforts
2. Engagement of the public using the latest communication methods including social networking.
3. Engagement of the public in new forums
4. Collection of data to evaluate the effectiveness of communication efforts

The Committee discussed submitting to the NAC a proposed finding that the STMD consistently lacks sufficient discretionary resources to deliver all the technology developments needed across the TRL spectrum to meet NASA's critical future mission goals. In response to a question from Dr. Condon, Mr. Bowersox explained that the purpose for the finding would be to raise awareness beyond the NAC that if technology funding were to be cut, Exploration progress would be adversely impacted. Dr. Siegel advised that the finding would be beneficial because it would show how technology development and Exploration are integrally linked. The Committee approved the following proposed finding:

NASA Advisory Council Finding

Space Technology Funding for Humans to Mars

Name of Committee: Technology, Innovation and Engineering Committee / Human Exploration and Operations Committee (*joint finding*)

Chair of Committee: Dr. William Ballhaus / Mr. Kenneth Bowersox
Date of Council Public Deliberation: July 31, 2015
Short Title of Finding: Space Technology Funding for Humans to Mars

Finding: The Technology, Innovation and Engineering Committee and Human Exploration and Operations Committee have common exploration, technology, and operational needs and goals. The two communities are working together on topics of common interest, and this collaboration can serve to optimize future mission success.
A well-defined plan for the implementation of the U.S. objective of humans to the surface of Mars is mandatory to adequately assess funding for timely development of the required technology. When the NASA Space Technology Mission Directorate (STMD) was established, a plan was formulated that included well-defined deliverables and the necessary budget to execute the program (Strategic Space Technology Investment Plan, 2012). However, the Council finds that STMD has consistently lacked sufficient discretionary resources to deliver all the technology developments required across the Technology Readiness Level (TRL) spectrum to meet NASA's critical future mission goals.

The Committee discussed submitting to the NAC a proposed finding on a perception that there is a need for greater detail in the plan for Exploration. Ms. Bartell explained that a "hard, concrete, firm plan" was not needed, but that additional communication on the early steps was needed. Mr. Gerstenmaier stated that NASA would not definitize a discrete plan all the way to Mars. Mr. Bowersox noted that additional details had been provided cislunar space plan and that further details can wait for technology development efforts. He explained that having the discussion was important.

Mr. Levin stated that HEOMD is going a good job on commercial space. He stated that he was impressed with the way Mr. McAlister and Mr. Gerstenmaier answered questions on the subject. Mr. Levin added that NASA's outreach program was also doing a good job, although he was disappointed that it only promoted NASA programs.

Dr. Siegel expressed appreciation to Ms. Valerie Chabot for providing support to the Committee "beyond the call of duty." Dr. Siegel adjourned the HEO Committee meeting at 5:40 PM.

NASA ADVISORY COUNCIL
Human Exploration and Operations Committee
MEETING
NASA Jet Propulsion Laboratory
Bldg. 186–von Kármán Auditorium
Pasadena, CA

July 27-29, 2015

AGENDA

Monday, July 27

NAC HEO COMMITTEE PUBLIC MEETING

10:00 – 10:10 am	Call to Order, Welcome and Opening Remarks	Dr. Siegel and Mr. Bowersox
10: 10 – 11:00	Status of the Human Exploration and Operations Mission Directorate	Mr. William Gerstenmaier
11:00 – 11:45	JPL Study of Humans to Mars	Mr. Firouz Naderi
11:45 -12:00	Discussion	Mr. Ken Bowersox
Noon – 1:00 pm	***LUNCH***	

NAC HEO /TECHNOLOGY, INNOVATION, AND ENGINEERING (TI & E)

JOINT MEETING IN Building 186 von Kármán Auditorium

1:00 – 1:00 pm	Call to Order and Welcome	Dr. Bette Siegel and Mr. Ken Bowersox Mr. Michael Green and Dr. Bill Ballhaus
1:00 – 2:00	Overview of Space Technology	Mr. Steve Jurczyk
2:00 – 3:00	Evolvable Mars Strategy – HEO Tech Develop. Efforts	Mr. Jason Crusan
3:00 – 3:15	***BREAK***	
3:15 – 3:45	Hydrocarbon Engine	Mr. Bill Hill and Mr. Jim Norman
3:45- 4:15	NASA Launch Services Overview	Mr. Jim Norman and Mr. Darren Bedell
4:15 – 5:30	Joint Discussion, Joint Recommendations and How We Work Together	
5:30	***ADJOURN Joint meeting***	

Tuesday, July 28

NAC HUMAN EXPLORATION & OPERATIONS COMMITTEE

8:00 – 8:05	Call to Order, Welcome and Opening Remarks	Dr. Bette Siegel and Mr. Ken Bowersox
8:05 – 9:00	Communications Strategy	Dr. Alotta Taylor
9:00 – 10:00	Exploration Systems Development Status	Mr. Bill Hill
10:00 – 10:10	***BREAK***	
10:10 – 11:10	Asteroid Redirect Mission Status	Dr. Michele Gates
11:10 – 12:00	Commercial Crew Program Status	Mr. Phil McAlister
12:00– 1:00	Lunch	
1:00- 1:50	International Space Station Status	Mr. Sam Scimemi
1:50-4:00	***BREAK***	
4:00 – 5:30	Discussion and Recommendations	
5:30	Adjourn	

Human Exploration and Operations Committee Membership
July 2015

Mr. Ken Bowersox *Chair*	Former NASA astronaut and retired U.S. Navy Captain
Dr. Bette Siegel *Executive Secretary*	NASA Headquarters
Ms. Shannon Bartell	Former Director of Safety & Mission Assurance, KSC
Ms. Nancy Ann Budden	Director for Special Operations Technology, Office of the Secretary of Defense
Dr. Leroy Chiao	Former NASA Astronaut and ISS Commander
Dr. Stephen "Pat" Condon	Aerospace Consultant, former Commander of the Ogden Air Logistics Center, the Arnold Engineering Development Center, and the Air Force Armament Laboratory
Mr. Joseph Cuzzupoli	Former Assistant Apollo Program Manager, Rockwell, and manager of the Space Shuttle Orbiter Project
Mr. Tommy Holloway	Former Space Shuttle and ISS Program Manager
Mr. Lon Levin	President, SkySevenVentures
Dr. David E. Longnecker	Director, Health Care Affairs, Association of American Medical Colleges (AAMC), member of the National Academy of Sciences Institute of Medicine (IOM)
Mr. Michael Lopez-Alegria	Former NASA astronaut and retired U.S. Navy Captain, President of the Commercial Spaceflight Federation
Mr. Richard Malow	Distinguished Advisor at the Association of University for Research in Astronomy (AURA)
Mr. James Odom	Former NASA Associate Administrator for Space Station Freedom
Mr. Bob Sieck	Former Space Shuttle Launch Director
Mr. James Voss	Former NASA astronaut and retired U.S. Army Colonel, Scholar in Residence, Department of Aerospace Engineering Sciences, University of Colorado, Boulder

Human Exploration and Operations Committee
NASA Headquarters
Washington, DC

April 7-8, 2015

MEETING ATTENDEES

HEO Committee Members:

Bowersox, Ken, *Chair*	U.S. Navy *(Ret.)*
Siegel, Bette, *Executive Secretary*	NASA Headquarters
Bartell, Shannon	Aerospace Consultant
Budden, Nancy Anne	Office of the Secretary of Defense
Cuzzupoli, Joseph *(via telecom)*	Aerospace Consultant
Chiao, Leroy *(via telecom)*	Aerospace Consultant
Condon, Stephen "Pat"	Aerospace Consultant
Holloway, Tommy *(via telecom)*	Aerospace Consultant
Levin, Lon *(via telecom)*	SkySeven Ventures
Longnecker, David	Association of American Medical Colleges
Lopez-Alegria, Michael	Commercial Spaceflight Federation
Malow, Richard	Association of Universities for Research in Astronomy
Odom, James	Aerospace Consultant
Sieck, Robert	Aerospace Consultant
Voss, James	University of Colorado, Boulder

NASA Attendees:

Baker, John	NASA JPL
Bedell, Darren	NASA KSC
Boggs, Kathleen	NASA HQ
Burdick, Garry	NASA JPL
Cook, Richard	NASA JPL
Coulter, Dan	NASA JPL
Crusan, Jason	NASA HQ
Day, Brian	NASA ARC
Eisenman, David	NASA JPL
Gates, Michele	NASA HQ
Herrmann, Nicole	NASA HQ
Hill, Bill	NASA HQ
Holt, Josh	NASA JPL
Jurczyk, Steve	NASA HQ
Kulczyeki, Stephen	NASA JPL
Law, Emily	NASA JPL
MacNeal, Bruce	NASA JPL
McAlister, Philip	NASA HQ
Muirhead, Brian	NASA JPL

Norman, Jim	NASA HQ
Price, Hoppy	NASA JPL
Rausch, Diane	NASA HQ
Reuter, Jim	NASA HQ
Schmidt, Greg	NASA ARC
Scimemi, Sam	NASA HQ
Seidel, David	NASA JPL
Smith, Marshall	NASA HQ
Taylor, Alotta	NASA HQ
Williams, Greg	NASA HQ

Other Attendees:

Blaisdell, Eva	California Space Center
Frankel, David	P B Frankel, LLC
Friedman, Louis	[not affiliated]
Richardson, Larry	ULA

Telecon Attendees:

Chabot, Valerie
Robinson, Shawanda
Atkinson, Loretta
Bowman, Mark
Broadwell, Marguerite
Buck, Josh
Campbell, Paul
Clark, Stephen
Dean, James
Eisen, Howard
Foust, Jeff
Gall, Carol
Gatens, Robyn
Gilbert, Chris
Griffiths, Jay
Guerrero, Jose
Hamilton, Catheryn
Harwood, Bill
Hay, Jason
Hopkins, Josh
Howard, David
Irving, Rick
Johnson, James
Young, Lee
Manning, Josh
McGuire, Andrew

McKay, Meredith
Oliveira, Justin
Oliver, Dawn
Passmore, Richard
Paxton, Megan
Perrotto, Trent
Read, Jennifer
Reichhardt, Tony
Scheld, Dan
Schierholz, Stephanie
Simberg, Rand
Smith, Marcia
Smith, Phil
Steitz, Dave
Thompson, Tabatha
Tomack, Bill
Vergano, Dan
Weigel, Elsie
Ziats, John
Zimmerman, Robert

Human Exploration and Operations Committee
NASA Jet Propulsion Laboratory
Pasadena, CA

July 27-28, 2015

LIST OF PRESENTATION MATERIAL

1) Human Exploration and Operations [Williams]
2) Human Journey to Mars – Thoughts on an Executable Program [Naderi, Price, Baker]
3) Space Technology Mission Directorate [Jurczyk]
4) Evolvable Mars Campaign and Technology Development [Crusan]
5) Domestic Hydrocarbon Rocket Main Engine [Hill, Norman]
6) Launch Services Overview [Bedell, Norman]
7) "Reach New Heights, Reveal the Unknown, Benefit All Mankind" [Taylor]
8) Exploration Systems Development Status [Hill]
9) Asteroid Redirect Mission Update [Gates]
10) Commercial Crew Program Status [McAlister]
11) International Space Station Status [Scimemi]

Other material distributed at the meeting:

Pioneering Space: Progress and Next Steps on the Journey to Mars, July 2015 Draft